MECHANICAL PROPERTIES OF CONCRETE MIXED WITH WASTE GLASS

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MECHANICAL PROPERTIES OF CONCRETE MIXED WITH WASTE GLASS

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Abstract The study of waste glass (WG) concrete mix was done to study mechanical properties of concrete mix with target characteristics strength 30MPa at 28 days age. The laboratory experimental study was conducted at Muhammadiyah University between October and December 2014, to find out the high strength and amount for Waste Glass as fine aggregates replacement in a concrete mix. Also alkali silica reaction (ASR) was determined by expansion test. For mechanical properties compressive strength, flexural strength and modulus of elasticity (MOE) were determined. All measurement was done in accordance to ASTM standard methods. Three sample content types of 10%, 15% and 20% concrete mix containing waste glass and control 0% concrete mix were prepared, casted and cured for 28 days before determination of mechanical properties, and mortar bar were caste and cured for 14 days for ASR determination. Results showed that highest measured characteristics strength was 30.72MPa, for flexural strength was 6.8MPa and for modulus of elasticity was 37.42MPa, and the high expansion test was 28% compared to control concrete mix. For the amount waste glass replacement was determined in relation to high characteristics strength yield which was found at 10% WG replacement. The conclusion reached to this study was; Maximum characteristic strength for glass concrete mix was reached with 10% fine aggregate replaced was 30.72Mpa at 28 days age. While for ASR, fine aggregate replacement by waste glass showed expansion at all amount replaced.

Keywords: waste glass, compressive strength, flexural strength, modulus of elasticity, alkali silica reaction

I. INTRODUCTION

As the concern increased in construction industries to find alternative for natural sand use in concrete, recyclable waste materials became currently and future trends of research on the use to manufacture coarse and fine aggregates for a Portland cement concrete mix. Crushed aggregate, bottom ash, foundry sand and various by-products are replacing natural sand and gravel in most countries. Among others glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. Most of developing country facing problem in technology of recycling of solid waste material resulting to detrimental environmental impacts related to waste glass. Landfill are not effectively done due to lack of knowledgeable personnel and finance problem, thus letting cities and towns prone to environmental pollution (Mageswari, et al., 2010; Gautam, et al., 2012; Siam 2011; Abbaspour 2012). Therefore glass is an ideal material for recycling and use of recycled glass helps in energy saving and environmental pollution reduction. One of its significant contributions is to the construction field where the waste glass reused for concrete production. The application of glass in architectural concrete had been improving as many laboratory experiments be conducted to explore the use of waste glass as coarse aggregates, fine aggregates and glass powder for considering the effects of Alkali-Silica-Reaction (ASR) for alleviation as well as the decorative purpose in concrete.

II . LITERETURE REVIEW

Amir Abbaspour (2012) on study about behaviors of Fine Glass Powders and Coarse Glass Aggregates on Concrete. The goal of the investigation was to study the effect of glass grain size on the nature of their reaction products for morphology and composition and to try to explain the consequences resulting from the differences. The main results observed that: Depending on coarseness or fineness, glass particles have different chemical behaviors. Newly formed gels vary in their chemical compositions and their mineralogical structures: first coarse glass grains labeled as C1 not completely attacked, were covered by a double layer of massive alkali gel; second Finer grains labeled C8, were completely dissolved. Also showed newly formed products resulting from fine particles have higher alkali contents resulting from C1. Lastly the study revealed the formation of phyllosilicates responsible for the alkali reactive behavior of C1, as opposed to C8 associated with pozzolanic predominate.

Idir, et al., (2009), Use of Waste Glass as Powder and Aggregate in Cement-Based Materials. They reported that depending on the size of the glass particles used in concrete, two antagonistic behaviors can be observed: alkali silica reaction, which involves negative effects, and pozzolanic reaction, improving the properties of concrete .The research work undertaken dealt with the use of fine particles of glass and glass aggregates in mortars, either separately or combined. Two parameters based on standardized tests were studied: pozzolanic assessment by mechanical tests on mortar samples and alkali-reactive aggregate characteristics and fines inhibitor evaluations by monitoring of dimensional changes. It was shown that there is no need to use glass in the form of fines since no swelling due to alkali-silica reaction was recorded when the diameter of the glass grains was less than 1mm. Besides, fine glass powders having specific surface areas ranging from 180 to 540m^2 / kg reduce the expansions of mortars subjected to alkali-silica reaction

III . RESEARCH METHODOLOGY

MATERIAL

Portland cement used was (OPC) Grade I, obtained from Gresik Supplier Indonesia .Coarse aggregates used was natural gravels from Merapi supplier of maximum size 20mm with a bulk specific gravity (SSD) of 2.67, and fine aggregates was natural sand of maximum size 4.75mm with bulk specific gravity (SSD) of 2.63. The waste glass obtained from Solo glass store was used as a replacement of fine aggregate.

Mixture Design:

Four types of concrete mixes were prepared for this study The controlled concrete mix ratio was1:1.36:2.32 (cement: fine aggregate: coarse aggregate) with the water-cement ratio of 0.44. The glass concrete mixes were summarized in Table 3with 10%, 15% and 20% partial replacement for the sand. Three specimens were prepared for each test and all concrete specimens were cured for28 days. Also mortar bar was prepared with mix of cement and fine aggregates the mix ratio of 1: 1.36 (cement: fine aggregates) to determine ASR and cure in 1N NaOH solution at 80^{O}C for 14 days.

Table 2. Mixtures Proportion

% Waste Glass	w/c ratio	Water kg/m3	Cement kg/m3	C. Aggregates kg/m3	Fine aggregates kg/m3	
					Sand	Glass
0 %	0.44	200	455	1056	621	0.00
10 %	0.44	200	455	1056	559	62
15 %	0.44	200	455	1056	528	93
20 %	0.44	200	455	1056	497	124

IV. RESULT AND DISCUSSION

1) Waste Glass Aggregate Test

In this study, the waste glass aggregate has used as planned to replace natural fine aggregate (sand). The waste glass used obtained from Solo city glass store, were hand crushed, and sieved for gradation, after washing process to get rid of dust and dried, and the researcher tested the waste glass aggregate properties during preparation and results shown in table 1.

Table .1. Fine aggregate test result

No.	Test Type	Result	Standard
1	Bulk specific gravity SSD	2.52	2.5 – 2.7
2	Fineness modulus	2.91	2.3 – 3.1

It is known that the glass aggregate resulting from crushed glass is different in terms of the properties from natural aggregates. The difference between those two can be seen in the properties such as the specific gravity and proportion of water absorption. The value of specific gravity was 2.63 for natural fine aggregates and 2.52for waste glass and the value of modulus of stiffness was 2.95 for natural fine aggregate sand 2.91 for waste glass aggregates respectively. Thus the SG of FA is high than that of WG aggregates similarly does the same for the value of modulus of stiffness. Although the value of specific gravity for natural coarse aggregate and fine aggregates are 2.67 and 2.63 respectively were high than that of waste glass all aggregate met the requirement of specific gravity as specifications of the gradation of the fine aggregate by ASTM C 127 and 128.

Based on the result of properties of waste glass aggregate and natural fine aggregate, it can be seen that specific gravity for natural fine aggregate was2.52 and specified standard limit was 2.5 – 2.7, thus it is within the required limit. On other hand sieve analysis for glass was done similar to fine aggregates, the results for sieve analysis , the allowed material to pass in a sieve maximum was 4.75mm and minimum was 0.15mm, the required aggregates was in between 4mm and 1.18 mm.

2) Slump Test

The test was conducted in accordance with ASTM C143. .

Table 2 Slump Test Result description

Batch No:	Mix Design	Slump Test Result (mm)
1	(0.44)w/c + 100% CA + 100%FA + 0%WG	95
2	(0.44)w/c + 100% CA + 90%FA + 10%WG	75
3	(0.44)w/c + 100% CA + 85%FA + 15%WG	68
4	(0.44)w/c + 100% CA + 80%FA + 20%WG	62

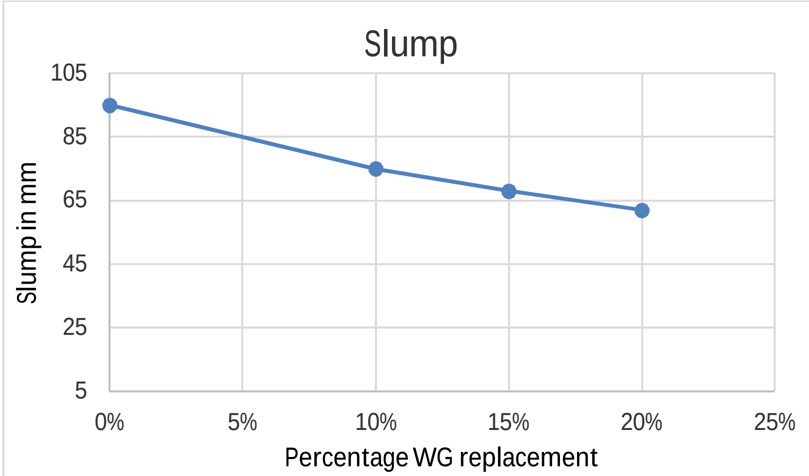

Figure: 1.Slump test for Fresh prepared WG concrete mix.

Based on the result of slump test, it can be seen that the result of slump test were decreased. With FA (100% sand) the mixture of 0% waste glass, the slump value was 95 mm, then when the waste glass were added as replacement of FA by10%, 15% and 20% the slump values obtained were, 75 mm, 68mmand 62mm respectively .Therefore, based on the research result of slump test, it can be observed that the addition of waste glass to the mixture design influenced the value of slump test. The value of slump test kept on decrease as more percentage of waste glass was added. This result showed similarity to previous study by Abdallah and Fan, (2014) reported the value of slump decrease as obtained from 80mm, 65mm, 56.5 to 52mm when 0% control 5%, 15% and 20% glass replacement in concrete respectively.

3) **Compressive Strength**

Compressive strength is defined as the maximum resistance of a concrete to axial loading. 16 specimen of 15cm x 15 cm x 15 cm size were prepared to test for characteristic strength, for every design mix sample four specimens were made. Testing of all four specimens to every sample design was carried out after curing for 28 days in accordance with ASTM C 39

Table 3.CharacteristicStrength (MPa)

		Specimen WG replacement %			
Batch Mix Design		0	10	15	20
Lab. Obtained Average target Strength at 28 Day	Kg/cm2	414.44	398.52	327.41	291.85
	Ft in MPa	40.58	39.02	32.06	28.58
Fck = Ft – 1.65S Ft - 8.25	Fck in MPa	32.28	30.72	23.76	20.28
Conversion Unit	1Kg/cm2 = 0.09791MPa source: Website : www.jindalpoly.com				

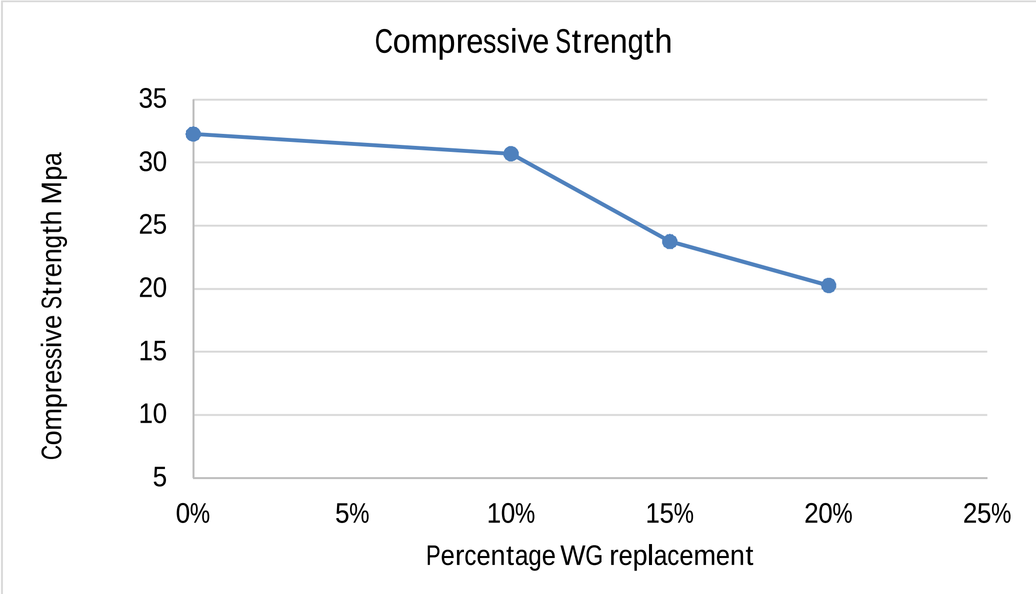

Figure 2.Characteristic Strength of WG concrete at 28 Days

Based on the data in table 3, it can be seen that the result of compressive strength for Control concrete (Normal) was above the average strength target ($fcr\ =\ 38.3$), and higher than that of WG concrete. Concrete made by replacement of FA with WG aggregate decreased the compressive strength as compared to control concrete. Control concrete with0% WG recorded characteristic strength was32.28Mpa, with replacement of natural FA by 10%, 15% and 20% WG, observed of compressive strength were 30.72MPa, 23.76MPa and 20.28MPa respectively. The recorded value for characteristic strength varied in comparison to specified compressive strength (30MPa) at age of 28 days. At 0 % and 10% WG replacement were above the specified characteristic strength and at 15 % and 20% were below specified characteristic strength and marginal specified characteristic strength. Even though all measured characteristics strengths were below the control concrete mix design as shown in table 3.

The observed result shows that the Characteristic strength of concrete keep decrease by 4.83%, 26.4% and 37.8% as waste glass replacement added by 10%, 15% and 20% respectively compared to control concrete of 0% waste glass. This result may suggest that the decrease in strengths was due to addition of waste glass amount in replacement which can be similarly compared to the observation made by previous researchers for example, Malik et al., (2013) studying for Concrete Involving Use of Waste Glass as Partial Replacement of Fine Aggregates observed that the maximum Characteristic strength measured was 25% more than that of reference mix at 28 days corresponding to concrete mix containing 20% waste glass in place of fine aggregates. But Characteristic strength for concrete mix with 40% waste glass content was found to be less than that of reference mix. Siam, (2011) observation in compressive strengths for variation of (0.4 as GF4), (0.5 as GF5), and (0.6 as GF6) water cement ratio (w/c) and WG replacement of (20, 40, and 60 percent) respectively. To his study high strength was recorded at 20% replacement to all type of % WG replacement although was lower compared to control concrete mix except when 0.4 w/c ratio were used. Also observation of effect for increasing percentage waste glass replacement in concrete mixture by decreasing its strength, were reported by (Ammash et al., 2009 and Bahoria, et al.,2013), as the more waste glass replaced in concrete the more the decrease in compressive strength.

4) **Flexural Strength**

Table 4.Flexural Strength (MPa) at 28 days.

	Specimen WG replacement %				
Batch Mix Design		0	10	15	20
Average Strength at 28 Day	Kg/cm^2	48.53	66.08	68.14	68.83
	MPa	4.8	6.5	6.6	6.8
Conversion	$1Kg/cm^2$ = 10.1972MPa source: Website : www.jindalpoly.com				

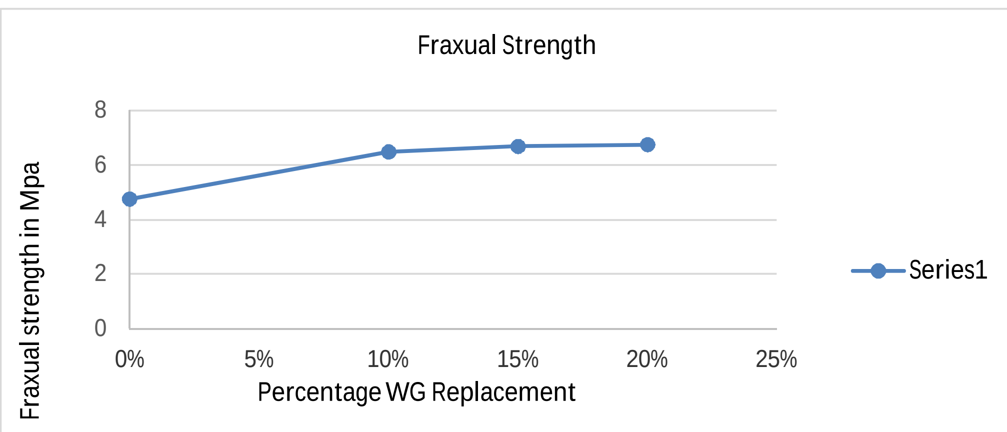

Figure. .3. Flexural Strength of WG concrete mix

From the table 4, based on the result of research, it can be seen that the result of flexural strength when used 0% of WG aggregate the average value of flexural strength was 4.8 MPa. Then, when replaced natural FA by percentage WG the average values was increased in all specimen tested. This increase in flexural strength shows the flexibility of concrete and stiffness of glass material in concrete. In replacement of FA by 10% WG the recorded flexural strength was 6.5MPa, at 15% WG flexural strength was 6.6MPa and at 20% WG flexural strength was 6.8MPa.

The increase in flexural strength observed in this work as percentage replacement of WG aggregates increased from 10%, 15% and 20% as compared to control concrete with 0% WG aggregates .The flexural strength were increased as compared to reference concrete with 0% WG replacement by 35.42%, 37.5% and 41.66% respectively .Until replacement of 20% WG the flexural strength increase observed to reach maximum increase, which can suggest the optimum replacement of waste glass in concrete mix. The similar trend was reported by Abdullah and Fan (2014) when investigated flexural strength in concrete test, results were clear that all mixes showed after 28-day, the flexural strength increased by 3.54%, 5.03 % and 8.92% when the waste glass content increased by 5%, 15% and 20% respectively. In addition Siam (2011) and Bahoria, et al., (2013), noted that the waste glass can increase flexural strength up to between 20 and 30 % replacement, beyond which the flexural strength of concrete decreased as percentage WG increased in concrete mix increased. Moreover, Shekhawat and Aggarwal (2014), in review noted the work proposed that flexural strength increases upto 35%replacement. Therefore waste glass can be used in concrete mix up to suggested optimum.

5) Modulus of Elasticity

Table .5. Modulus of Elasticity (MOE) at 28 days as ASTM C 469

Specimens ID	0%	10%	15%	20%
MOE (MPa)	32.400	35.560	36.055	37.420
% Increase	0%	9.375	11.28	15.625
$Ec = 4700\sqrt{fc'}$	26,728	25,249	22,150	20,188
% Decrease	0 %	5.53	17.13	24.47

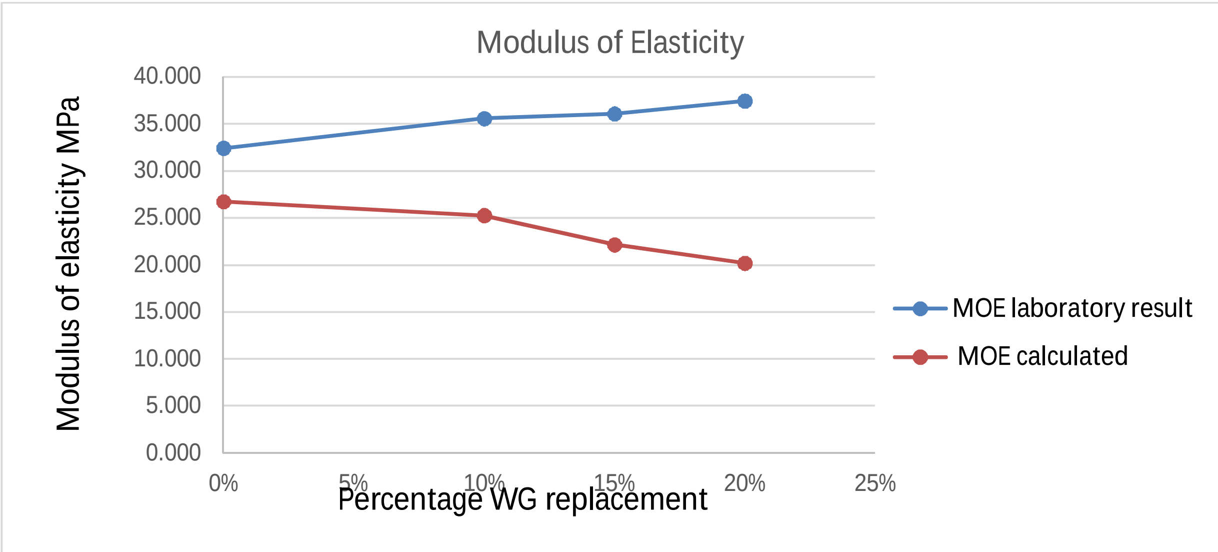

Figure: 4. MOE WG concrete for 28 days age. Research Result (2014)

The modulus of elasticity (MOE) of waste glass concrete mix at 28 days curing shown in table 5 and in figure 4. Observation of laboratory experiment on specimens for MOE showed increase by 9.375%, 11.28%, and 15 .625% respectively as the waste glass content increased to 20% and the trend of increased in MOE is linear. Therefore increasing amount of glass for replacement influence the MOE positively, this can be nature of glass material related to elasticity in stretching. Also similar trend observation reported by Abdallah and Fan, (2014), the modulus of elasticity (MOE) of the waste glass concretes at 7, 14 and 28 days curing. Overall, the trend of change in the MOE is very similar increased by 2.54%, 5.45% and 9.75% respectively as the waste glass content increased by 5%, 15% and 20%. In general this could also be attributed to a high modulus elasticity of glass compared to that of natural sand.

On the other hand MOE from experimental results showed different when compared to MOE calculated using the formula ($Ec = 4700\sqrt{fc'}$) as shown in table 4.13. The MOE of the formula decreased as the amount of glass for replacement was added from 10%, to 20% as compared to reference concrete with 0% glass replacement. The percentage decrease recorded was 5.53,17.13 and 24.47, at 10%, 15% and 20% replacement respectively., although the laboratory result similar to that reported by Abdallah and Fan (2014). Therefore taking trend in general experimental MOE of waste glass concrete replacement is linearly increased as percentage of WG replacement increased from 0% to 20%, the same to decrease does to MOE formula.

However, there is slight different in trend of increase that can be due to differences factors including ;size of aggregates and means of gradation, source of aggregates, target characteristic strength, water content ratio, cement type (quality)and error in measurement, still the observation can be taken for comparison .The numbers of research reported experimental results in MOE of glass mix concrete are limited, more study have reported experimental results on compressive, flexural and tensile strength. Therefore, this result may steer the need for more experimental studies to compare with the results of MOE form the formula.

6) **Alkali Silica Reaction (ASR) ASTM C 227and C 1260**

The Alkali–silica reaction (ASR) is used to determine any adverse reaction in concrete which occurs between the active silica that resides sometimes in aggregates and alkali that exists in cement

Table 6 : ASTM C 1260 Expansion Test Results

% WG	% Expansion					
	Day 0	Day 3	Day 5	Day 7	Day 10	Day 12	Day 14
A 0%	0	0.0	0.0	0.0	0.0	0.01	0.01
B10%	0	0,04	0,04	0,08	0,08	0,12	0,16
C 15%	0	0,04	0,04	0,08	0,12	0,16	0,2
D 20%	0	0,04	0,08	0,12	0,2	0,24	0,28

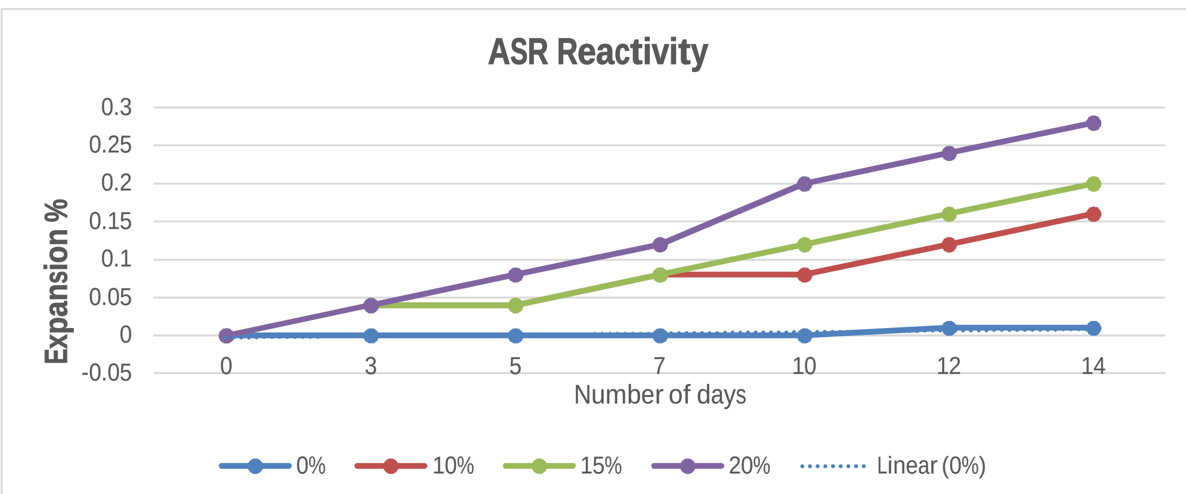

Figure 5. Graphical illustration of ASR expansion test Results

Based to this results ASR resulted from glass aggregates in concrete were observed as number of days the expansion were linearly increased, and record observed from day 3 through day 14 for mix types; B 10%, the record were (0.04, 0.04, 0.08, 0.08, 0.12 and 0.16); C 15% the record were (0,04, 0,04, 0,08, 0,120,16 and 0,2) and D 20% the record were (0,04, 0,08, 0,12, 0,2, 0,24 and 0,28) as shown in table 4.16, for increased number of days respectively. Also as WG percentage replacement increased, the same it does to ASR expansion percentage increased for 0.16, 0.2 and 0.28 percent for 10% < 15% < 20%, WG replacement respectively as shown in table 6. The percentage increases in expansion associated to ASR were 0.15%, 0.19% and 0.27% as compared to control concrete with 0% WG replacement which recorded 0.01% expansion until day 14 day age of waste glass concrete mix. The observed expansion in mortar bar can be associated with size of fine aggregates used since was high than 1mm, the range of fine aggregates used was sieved and graded between 4.75 to 1.18mm proportional glass aggregates was used. Although other factor such as water-cement (w/c) ratio, percentage air content in fresh concrete mix (% air), aggregates-cement ratio (Ferraris,1995).

Idir *et al.,* (2009) as studded the Use of Waste Glass as Powder and Aggregate in Cement-Based Materials. They reported that depending on the size of the glass particles used in concrete, two antagonistic behaviors can be observed: alkali silica reaction, which involves negative effects, and pozzolanic reaction, improving the properties of concrete. The research work undertaken dealt with the use of fine particles of glass and glass aggregates in mortars, either separately or combined. They observed that the expansion due to ASR was proportional to the size of aggregates used, as aggregates was higher than 1 mm size the expansion was noticed as in C0 and C1 specimens ID for 20% and 40% fine aggregates replacement, otherwise was observed no effect for aggregates below 1mm size but increased the strength of concrete.

Therefore, to sum up the observed ASR expansion result in current study have agreed to the previous study that relate the expansion for concrete containing glass aggregates with the size of aggregates, since the waste glass aggregates used in this experiment was high than 1mm in size as shown in table 6. for sieving program.

V. CONCLUSION AND SUGGESTION

1. Conclusion

The study for Mechanical properties of waste glass concrete mix on compressive strength, flexural strength and modulus of elasticity were done with the main goal being to determine the optimum amount of waste glass replacement in a concrete that yield the high strength at age of 28 days corresponding to specified characteristic compressive strength of standard concrete mixes. In addition ASR were measured within fourteen days. Based to illustrative figures, analysis presented in results and discussion above this study results concluded as the following:

1. Based on the IS 456:2000 for standard characteristic compressive strength the maximum waste used to replace the fine aggregates was about 10%.
2. Based on the Alkali Silica Reaction (ASR) expansion test, The maximum expansion was recorded with mix type D 20% at 14-daysis 28%.
3. Based on the results of this study mechanical properties determined were observed as;

   i). the characteristic compressive strength that meet IS 456:2000 was determine to be 30.72MPa at 28 days.

   ii). the high flexural strength determined was 6.8MPa at 28 days increased for 41.66% as compared to control concrete mix.

iii). the experimental MOE up to 20% WG replacement increased up to 37.42MPa as compared to 35.41MPa of control concrete mix. However, calculated MOE decreased as waste glass replacement increased.

4. In addition, for all the increment ratio of waste glass replacement, the compressive strength at 28 days were lower as compared to control concrete mix and also as compared to Modulus of elasticity to all designed concrete mix samples.

2. Suggestion

1. More experiment to be done for MOE of glass concrete mix to compare with calculated MOE.
2. Studies in ASR for use of fine glass aggregates with relation to other factors are needed.
3. The use of waste glass in concrete mix should take consideration to the mitigation of ASR that can develop and cause problem for the building.

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